Non-destructive Measurement of Moisture Distribution in Wood Using 3D X-ray Scanning and Electrical Resistance

Wanzhao Li[1], Jan Van den Bulcke[1], Imke De Windt[1], Denis Van Loo[2], Manuel Dierick[2], Loes Brabant[2], Joris Van Acker[1]

[1]UGCT – Woodlab-UGent, Department of Forest and Water Management, Faculty of Bioscience Engineering, Ghent University, Coupure Links 653, 9000 Ghent, Belgium [email: Wanzhao.Li@UGent.be]

[2]UGCT – Department of Physics and Astronomy, Faculty of Sciences, Ghent University, Proeftuinstraat 86, 9000 Ghent, Belgium [email: Luc.VanHoorebeke@UGent.be]

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ABSTRACT

Moisture substantially influences the strength and durability of wood material. Therefore, it is crucial to non-destructively monitor the moisture content (MC) and moisture distribution in wood when it is applied as a construction material. In this research, both the electrical resistance and 3D X-ray scanning are used to measure the moisture distribution, more specifically the relationship between the structure of plywood and the moisture distribution is studied. The results show that the electrical resistance measurement method, in combination with X-ray scanning, could effectively monitor the moisture distribution in wood products and as such can be beneficially used as complementary techniques.

1. INTRODUCTION

Wood is increasingly used as a construction material thanks to its renewability and sustainability. However, wood is easy to attack by fungi when the moisture content (MC) is higher than fibre saturate point (FSP) and other environmental conditions are favourable as well (Walker JCF 1993). Hence, it is crucial to continuously monitor the moisture content and distribution in wood products when they are used as a construction material in outdoor conditions. Van den Bulcke (2009b) and co-workers continuously weighed plywood exposed in weather condition to get the average MC of the specimens. To further get an idea on the moisture distribution, other authors have cut samples into small pieces and weighed separately (Macindoe and Leonard 2012). Obviously, this destructive method cannot continuously monitor the moisture distribution. X-ray scanning, as a non-destructive approach, can reveal the density distribution in wood products (Chen et al. 2009, De Ridder et al. 2011). The moisture distribution could be further derived taking into account the X-ray absorption of water. Compared with above methods, the electrical resistance MC measurement method is a reasonable accurate and non-destructive method (Brischke et al. 2008). The target of this research is to monitor the MC distribution in plywood by using X-ray scanning and electrical resistance methods as complementary techniques. As such the relationship between the internal structure of plywood and the MC distribution can be studied in detail.

2. EXPERIMENTAL

2.1. Preparation of the specimens

Spruce plywood, with PF glue (phenol formaldehyde), was sawn to the size of 70 x 50 x panel thickness mm^3. The specimen was without decay, knots and obvious defects. Two holes of 4 mm diameter were drilled in the specimen. The distance between the centers of the holes was 30 mm. Inside the 4 mm drill hole, another small hole with 1 mm diameter was drilled starting from the bottom of the former drill hole. Then, all four sides of the specimen were sealed. Next, the electrodes were glued in the predrilled holes with conductive and isolating glue as described in Brischke et al (2008). The electrodes were made of stripped commercial electric wires. In order to avoid beam hardening and metal artefacts in X-ray CT scanning, thin metal wires were used in this experiment. Finally, they

were mounted on stainless steel grids to avoid complete submersion and placed in the water for 16 days (384 hours). During this period, the electrical MC was recorded every 24 hours and the samples were scanned after 0, 24, 48, 96, 168, 216, 264, 336, 384 hours of immersion.

2.2. X-ray scanning and image processing

The specimens were scanned with the CT scanning set-up built at the Ghent University Centre for X-ray Tomography (www.ugct.ugent.be). The scanner is similar to the one as described in Masschaele et al. (2007) and used in Van den Bulcke et al. (2009a). The scan settings and test set-up were optimized to limit scan time to 6 minutes per specimen and avoid drying. Reconstruction was performed with Octopus, a tomography reconstruction package for parallel, cone-beam and helical geometry (Vlassenbroeck 2007) and includes also phase correction and retrieval algorithms (Paganin et al. 2002, Grosso et al. 2006, De Witte et al. 2009). An approximate voxel pitch of 100µm was obtained.

3. RESULTS AND DISCUSSION

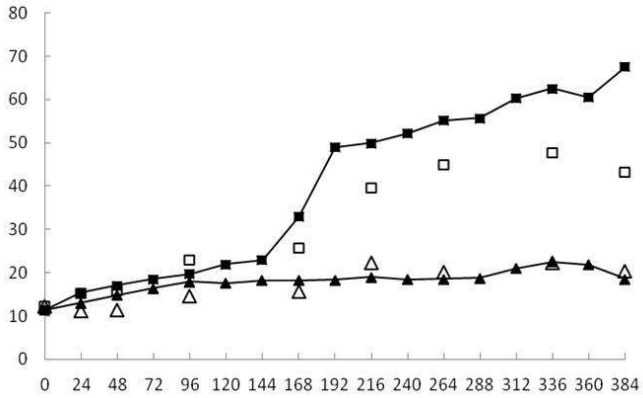

Figure 1: *The MC of spruce plywood.□= X-ray MC of 2nd layer,■= electrical MC of 2nd layer, △= X-ray MC of 3rd layer,▲= electrical MC of 3rd layer*

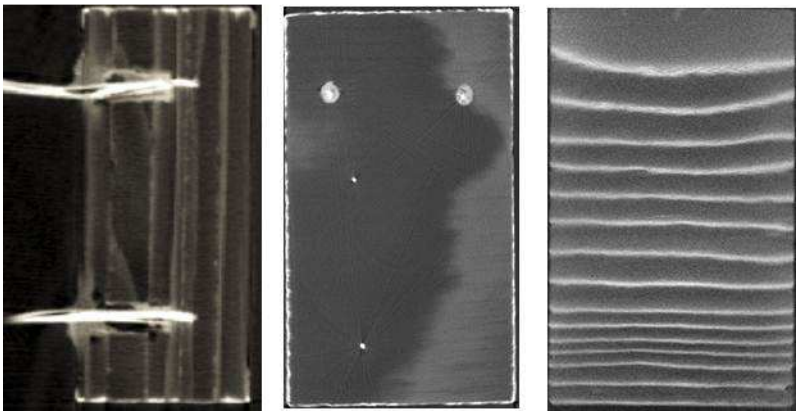

Figure 2: *CT image of spruce plywood and solid wood (right)*

The MC distribution among layers of plywood is different because adhesives can slow down moisture movement. Figure 2 shows the internal structure of spruce plywood and as a reference the internal structure of spruce solid wood. Due to the distinct microstructure, the moisture distribution in earlywood and latewood is different, which can influence the MC distribution in the different layers. Hence, the electrical MC measurement method could efficiently monitor the moisture distribution in plywood when the positions of the probes are reasonable and the MC is below 25% (Figure 1). Because the minimum MC for fungal decay is higher than FSP(25%−30%), the electrical resistance combined with X-ray scanning method could be used to record the time of decay risk. Ultimately, the probability of deterioration of the veneer could be estimated based on such measurements.

4. CONCLUSIONS

X-ray scanning is a valuable technique, which can monitor the MC distribution and internal structure of plywood. In combination with the electrical MC measurement method, which can continuously monitor moisture distribution in-service in plywood, both techniques are complementary. In future research, the electrical MC measurement method, combined with frequent X-ray tomography scanning, will be used to continuously monitor the MC distribution of wood samples exposed outdoors. More detailed information about moisture distribution and the influence of the internal structure will be given on the conference.

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